PREFACE

In a plasma equilibrium state it is usual to enquire what happens if one of the parameters is slightly perturbed. If the perturbation grows, the equilibrium is said to be unstable, if it decays the equilibrium is said to be stable. Plasma instability is a process by virtue of which a small perturbation is amplified.

Laboratory or space plasmas are normally not in thermodynamic equilibrium. This implies that a certain amount of free energy is stored in the plasma. This energy may be converted into a violent motion of the plasma or into radiation of electromagnetic waves. Plasma instability is a process where such a conversion takes place in a collective way. In other words it may be considered as a process in which a small perturbation in a plasma equilibrium state starts growing with time or space. In a practical sense instability often represents the ability of a plasma to escape from the configuration of fields that would otherwise contain a single charged particle indefinitely. Plasma instabilities can be classified as (a) Macro - (or configuration space) instabilities which are associated with departures of macroscopic quantities from equilibrium (b) Micro - (or velocity space) instabilities which are associated with departures from the equilibrium (Maxwellian) particle velocity distribution.
Plasma equilibria can now be obtained in several different geometries which are stable to large scale macroscopic instabilities. For instance in a tokamak a sufficiently large value of the safety factor gives stability against the important MHD modes and the minimum B geometry of the mirror machine stabilises the flute or interchange mode in that device.

In contrast to the macroinstabilities, it is not well known that how to stabilize microinstabilities, in fact it is quite likely that not all of them can be stabilized, and the best that one can probably do is alter the field geometry of a particular device to minimize their effect. Their high growth rate and short scale lengths mean that most microinstabilities will grow rapidly into the non-linear regime, when their growth will be limited. They are thus not expected to be as large-scale and chaotic as macroinstabilities. However, they can cause rapid, small scale, but relatively ordered plasma transport, and hence be very detrimental to plasma confinement.

There are two main sources of free energy which are available for driving micro-instabilities. First, there is velocity space anisotropy, examples of this are the ion distribution of a mirror machine which has an inherent loss-cone nature or the distortion of the distribution due to the plasma current as in a tokamak. The second main source of
free energy is the plasma expansion energy which is a consequence of the fact that a confined plasma necessarily has gradients of density and temperature.

During the past thirty years the linear theories of microinstabilities have been intensively studied theoretically. Rather than attempt to list every microinstability in the present thesis, I shall concentrate on one of the most important, the drift or universal instability to illustrate the theoretical techniques and findings that may be useful for the laboratory plasma devices as well as for the space plasma.

In a plasma which is inhomogeneous we find that as well as the class of homogeneous plasma waves, there is also another class of waves whose characteristics depend on the presence of a density gradient. The most important member of this class is the drift wave.

In the plasma either in laboratory or space the complete homogeneity can not be achieved. If the magnetized plasma has gradients in density or temperature the particles have associated drifts. Under these conditions plasma oscillations may be excited and move across the magnetic field with a phase velocity of the order of drift velocity of the plasma. These oscillations are known as drift waves. If the phase velocity of these waves is of the order of or smaller than the drift velocity of the particles these waves may be
spontaneously excited. These excited drift waves are highly supported by gradients and the kinetic energy of particle drifts transferred to these waves, creating the instability in the plasma. The drift waves propagate mainly perpendicular to both magnetic field and gradients.

The drift instabilities were studied first in the laboratory. In the presence of temperature gradient in an inhomogeneous plasma, waves propagating exactly across the magnetic field are unstable and that the phase velocity of these waves are similar to the drift velocity of the particles. Drift wave instabilities have been of current interest in various plasma confinement devices like, tokamak, Q - machines, mirror devices etc.

Sharp density gradients appear in a variety of geophysical processes in the space plasma. The existence of drift waves at the plasmapause has been reported and analyzed by various workers. The existence of electrostatic ELF waves were found at the plasmapause and their polarization and spatial relationship to the plasmapause density gradient are consistent with the drift wave origin. Sharp density gradients also occur owing to the particle precipitation in the auroral zone. Rocket and satellite data have also indicated the presence of intense electrostatic waves at the edge of an auroral arc with wave lengths near to ion gyroradius. These observations have been explained in terms of drift wave instability.
Another region of drift wave instability reported in the near space is the equatorial electrojet. The theory of gradient drift instability has been also used to explain the equatorial spread-F phenomena. The steep density gradient at the bottom side of the F-region provides the free energy for this instability.

Recently drift waves have been observed in various radio frequency heated plasma fusion devices. The drift wave may be stabilized/destabilised by the use of rf fields around the ion cyclotron frequencies. The effect of a high frequency powerful pump wave on high and low latitude E region gradient drift instability has been studied by many workers in the context of ionospheric modification (heating) experiments.

Which model should one use to describe a plasma, macroscopic or microscopic? The answer depends upon the problem under consideration. For example the kinetic model is in principle, more accurate than fluidmodel although it may lead to an insoluble mathematical problem. Some times a less accurate answer from macroscopic theory will do, and in some limiting cases the fluid model is even exact. In tenuous or high temperature plasmas, where collisional encounters between the constituent charged particles are rare, an understanding of plasma phenomena requires a knowledge of the individual particle trajectories in the self consistent electromagnetic fields.
Many phenomena can however be investigated and explained on the basis of elementary orbit theory in given externally imposed fields. The theoretical developments in the present thesis are based on the evaluation of particle trajectories in the presence of an electrostatic drift wave. This methodology is termed as particle aspect analysis.

This thesis contains five chapters dealing with the various aspects of electrostatic drift instability. The application and importance of the instability have also been indicated for the space and laboratory plasmas. The observational and theoretical developments for drift wave instability either for space or laboratory plasma are vast, therefore, the coverage of many aspects is beyond the scope of this study. We have investigated only few aspects of the instability for space and laboratory plasmas.

In this first chapter drift wave instability has been studies using loss-cone distribution function by investigating trajectories of charged particles in the presence of wave electric field. A low $\beta$ (ratio of plasma pressure to magnetic pressure) plasma, consisting of resonant and non-resonant particles, has been considered. It is assumed that the resonant particles participate in energy exchange with the wave whereas non-resonant particles support the oscillatory motion of the wave. Dispersion relation has been derived in electrostatic approximation and growth rate is evaluated by energy
conservation method. Effects of steepness of loss-cone distribution with temperature anisotropy are discussed on the dispersion relation and growth rate of the instability. Destabilizing effects due to steepness of loss-cone and temperature anisotropy have been predicted.

In the second chapter drift waves have been studied using single particle approach in the presence of inhomogeneous electric field applied perpendicular to the ambient magnetic field and for different distribution functions. Two groups of plasma particles have been considered, the non-resonant and the resonant one. It is assumed that the resonant particles participate in the energy exchange with the wave and non-resonant particles support the oscillatory motion of the wave. Expression for dispersion relation and growth rate have been derived and effects of distribution index and inhomogeneous electric field have been discussed using plasmapause parameters.

Third chapter deals with the general distribution function to investigate the effects of loss-cone on the drift wave instability in the presence of high frequency AC electric field applied perpendicular to the ambient magnetic field in a low β plasma. The dispersion relation and growth rate for the wave have been obtained by considering trajectories of the charged particles in the presence of drift wave and pump AC electric field. The dispersion relation is derived in
electrostatic approximation and the growth rate is evaluated by wave particle energy exchange method. The applied AC electric field modifies the dispersion relation significantly. The destabilizing effects have been observed for the steep loss-cone distributions. AC frequencies near the ion cyclotron frequency are found most effective to enhance the growth rate. The applicability of the theory has been indicated for r.f. laboratory plasma devices and ionospheric modification experiments.

In the fourth chapter electrostatic drift waves are studied in the presence of ion and electron beams with various distribution functions. The method of particle aspect analysis has been adopted to evaluate dispersion relation and growth rate of the wave. It is assumed that a low $\beta$ (ratio of plasma pressure to magnetic pressure) plasma is composed of resonant and non-resonant particles. The resonant particles participate in the energy with wave while non-resonant particles support the oscillatory motion of the drift wave. The energy exchange between wave and particles has been considered and hence the growth rate is derived by considering energy conservation. Marginal stability criteria has been discussed. The effect of ion and electron beam velocities has been discussed on the dispersion relation and growth rate for the various distribution index. The increase of growth rate with the distribution index is predicted. Dispersion relation and growth rate are
calculated for space plasma parameters and applicability of the theory has been indicated.

Fifth chapter describes the theory of particle aspect analysis for the drift wave in the presence of an inhomogeneous magnetic field and applied electric field parallel to the ambient magnetic field. The effect of parallel electric field is included in the zero order distribution function through the modification of particles thermal velocity in that direction. The plasma under consideration is assumed to be anisotropic and a low $\beta$ plasma. The dispersion relation and growth rate are evaluated and discussed for the particular plasma parameters. The limitations of the theory have been also pointed out.

The initial start and development of this work was made under the guidance of Dr. M. S. Tiwari whereas the execution and completion of the work described in thesis was achieved by the author. The papers have been published in the international journals of repute under the joint authorship with Dr. M. S. Tiwari and some of them are under the process of publication. The work submitted in this thesis was not submitted earlier for the award of Ph.D. degree.

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